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SUGAR AS FOOD.

BY

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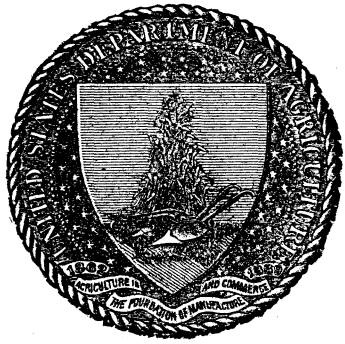
PREPARED UNDER SUPERVISION OF OFFICE OF EXPERIMENT STATIONS.



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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
Washington, D. C., February 4, 1899.

SIR: I have the honor to transmit herewith an article on sugar as food, prepared by Mrs. Mary Hinman Abel, in accordance with instructions given by the Director of this Office.

In preparing the article Mrs. Abel has made an extended study of the literature of the subject and has had the opportunity of discussing doubtful points with specialists in physiology and hygiene.

The work of the Division of Chemistry of the Department has been drawn upon as well as the results of the nutrition investigations conducted under the direction of this Office.

The relatively small number of definite investigations regarding the food value of sugar which have been found is a matter of some surprise. There are a number of points concerning the actual food value of this staple article of diet which are rather matter of opinion than established fact. This emphasizes the need of experiments along these lines.

It is believed that this article is a useful summary of available information concerning sugar as a food, and its publication as a Farmers' Bulletin is therefore respectfully recommended.

A. C. TRUE,
Director.

Hon. JAMES WILSON,
Secretary of Agriculture.

CONTENTS.

SUGAR AS FOOD.

EXTENT OF THE USE OF SUGAR.

The pleasant flavor of sugar, together with what we now know of its nutritive value, will account for its great popularity as a food. It may almost be said that people eat as much sugar as they can get, and the consumption of sugar in different countries is, in general, proportional to their wealth.

The English-speaking people are the largest consumers of sugar. In 1895 England consumed 86 pounds per capita and the United States 64 pounds, although still larger amounts are said to be consumed in sugar-growing districts, largely in the form of the ripe cane. Denmark and Switzerland consumed in the same year 45 pounds per capita, and Germany, France, and Holland about 30 pounds. Near the end of the list are Italy, Greece, and Turkey, with a consumption of less than 7 pounds per capita. The consumption of sugar is everywhere increasing. Seven to eight million tons are used annually in the different countries of the world.

CHEMICAL COMPOSITION OF SUGAR.

By the term sugar as here used, is meant cane sugar, so called because it was first manufactured from the sugar cane, although it is also found in the juice of a number of plants. Besides cane sugar there are a number of other sugars, as grape sugar, fruit sugar, and milk sugar. Considered chemically, all sugars are carbohydrates; that is, bodies composed of the three elements—carbon, hydrogen, and oxygen—the oxygen and hydrogen being in the same proportion as in water, which is made up of two atoms of hydrogen and one of oxygen. The principal carbohydrates which serve as food may be classified as follows: (1) Monosaccharids, including hexoses, such as glucose, or grape sugar, and levulose, or fruit sugar, made up of 6 atoms of carbon, 12 atoms of hydrogen, and 6 atoms of oxygen; (2) disaccharids, such as cane sugar and milk sugar, made up of 12 atoms of carbon, 22 of hydrogen, and 11 of oxygen, and (3) polysaccharids, such as starches, made up of 6 atoms of carbon, 10 of hydrogen, and 5 of oxygen, this combi-

nation being repeated an unknown number of times. It will be seen that the second group is twice the first minus the elements of water, and that the third is the same as the first minus water. When by chemical means water is added to the second group, it is separated into two hexoses, and when water is added chemically to group 3, two or more hexoses are formed. This process is called inversion, or hydrolysis, and may be produced in a number of ways. It is spoken of later. It will be seen that each group contains a number of different members; for example, grape sugar and fruit sugar have the same chemical composition. This does not mean that they are identical bodies. Their difference in properties is explained on the ground that although they contain the same kinds of elements with the same number of atoms, the atoms are differently grouped. This must not be confused with the fact that the same sort of sugar may be obtained from widely different sources; thus, grape sugar is found in grapes and other fruits, and cane sugar is found in the juice of the sugar cane, beets, carrots, and other plants.

CHARACTERISTICS OF CANE SUGAR.

In appearance pure cane sugar consists of a mass of white crystals. It dissolves easily in about one-half its weight of cold water and in still less of hot water. It is very sweet to the taste, two and one-half times as sweet as grape sugar.

At 320° F., which is considerably above the boiling point of water (212° F.), sugar melts into a colorless liquid which rapidly takes on an amber hue. If cooled at this point, it hardens into a glassy mass, transparent and brittle, called "barley sugar." If heated still higher, it browns, becoming less sweet and taking on a bitter flavor. This browned sugar is called caramel. Old-fashioned brown sugar owed its color and flavor, in part, at least, to caramel, for, as sugar was formerly made, in the process of evaporation over the open fire some of the sugar was caramelized or half burnt, since in the final stages the mass became so thick that it could not move about freely and exchange heat, and the layer next to the bottom of the kettle was raised far above the boiling point.

CHARACTERISTICS OF OTHER KINDS OF SUGAR.

As already stated, there are other sugars besides cane sugar. The one most frequently met with is dextrose or grape sugar, which is much less sweet than cane sugar and differs from it chemically. It may be seen in yellowish grains in the raisin and is found in small quantities in other fruits. Dextrose chiefly occurs, however, as the result of the change known as inversion, which takes place in cane sugar, starch, etc., when heated in a solution with dilute acids or when treated in some other way to induce hydration—i. e., cause them to unite chemically with water. Cane sugar in this case splits up into a mixture of

dextrose and levulose, known as "invert" sugar. The commercial glucose is dextrose made by hydrolizing starch.

Cooks have often observed that more sugar is necessary in sweetening acid fruits if it is heated with them from the first than if it be added when the cooking is completed. This is because some of the cane sugar, acted on by the heat and acid, has been changed to those other bodies which are less sweet. The effect of heat and acids in "inverting" cane sugar has constantly to be kept in view in the manufacture of sugar. By the slow methods formerly in use on the sugar plantations the juice of the cane was already sour when the boiling began, and these acids in the presence of heat inverted much of the cane sugar, and the mischief was further increased because the very presence of glucose or of caramel in a solution of cane sugar renders the crystallization of the sugar very difficult. The confectioner knows that if he wishes to prevent a concentrated solution of sugar from crystallizing, as in making "fondant" or soft filling for bonbons, he has but to add a small proportion of commercial glucose.

The change of cane sugar in solution to dextrose and levulose is brought about to some extent by the action of heat, even when no acid is present. It is also caused by the action of certain ferments, such as invertin, an enzym which occurs in connection with yeast, and by ferments found in the intestinal tract.

Milk sugar is another important sugar. Milk yields from four to five per cent of this form, and it is not found elsewhere. It is said to be the most digestible sugar for infants.

Honey as stored by the honeybee was formerly very highly prized as a food and flavor. This is less the case since cane sugar has become so cheap and plentiful. In addition to very small quantities of cane sugar, honey consists of a mixture of glucose and levulose (about 37 per cent of each). Honey also contains water and a small amount of mineral matter. It owes its flavor to volatile bodies found in the flowers from which it is obtained, and this flavor varies according to the source from which the honey is gathered, that from some flowers having a more agreeable flavor than that from others. Honey has been used from the earliest times, and is generally regarded as wholesome in moderate amounts. Strained honey is very frequently adulterated with commercial glucose sirup and other materials. While there is no reason for assuming that the manufactured glucose, if properly prepared, is more harmful than the glucose found in fruits, it is a cheaper article, and the fraud consists in selling a low-cost article under a false name for a high price.

Glycogen is a carbohydrate having the same chemical composition as starch. It has, however, different chemical properties. Glycogen is found in small amounts in muscular tissue, and more abundantly in the liver, where it may exist, indeed, in considerable quantity. It serves an important function in nutrition, being stored by the animal body as a reserve material.

SOURCES OF CANE SUGAR.

Cane sugar, sucrose, or simply sugar, as it is known to commerce and in the household, exists dissolved in many vegetable juices. It is found in the stems and roots of all the grasses, especially in the sugar cane and sorghum; in fleshy roots, as the beet, carrot, turnip, and sweet potato; in the sap of trees, as the date palm and sugar maple; in almost all sweet fruits, and in the nectar of flowers; but in only a few of these is the proportion of cane sugar large enough to make profitable its separation from the other substances which these juices hold in solution.

The manufacture of sugar as at present known is an art that has developed from crude beginnings. Sugar is a staple article of food, just as is bread or meat, but few people realize that, unlike meat and bread, it has been a staple food for but a few generations. Only, indeed, in the last half century has it been produced in such quantities and at such a price as to bring it within the reach of all classes of people.

THE SUGAR CANE.

The sugar cane is a gigantic jointed grass (*Saccharum officinarum*), native in eastern India and China, numerous varieties of which are now grown in the tropical and subtropical regions of both hemispheres.

Sugar from the sugar cane was probably known in China 2,000 years before it was used in Europe. When merchants began to trade in the Indies it was brought westward with spices and perfumes and other rare and costly merchandise, and it was used for a long time exclusively in the preparation of medicines. An old saying to express the loss of something very essential was "Like an apothecary without sugar." Greek physicians several centuries before the Christian era speak of sugar under the name of "Indian salt." It was called "honey made from reeds," and said to be "like gum, white and brittle." But not until the Middle Ages did Europeans have any clear idea of its origin. It was confounded with manna or was thought to exude from the stem of a plant, where it dried into a kind of gum. When in the fourteenth or fifteenth century the sugar cane from India was cultivated in northern Africa the use of sugar greatly increased, and, as its culture was extended to the newly-discovered Canary Islands and later to the West Indies and Brazil, it became a common article of food among the well-to-do. In 1598 Hentzer, a German traveler, thus describes Queen Elizabeth, then 65 years of age: "Her nose is a little hooked, her lips narrow, and her teeth black, a defect the English seem subject to from their great use of sugar." By many the new food was still regarded with suspicion. It was said to be very heating, to be bad for the lungs, and even to cause apoplexy. Honey was thought to be more wholesome, because more natural than the "products of forced invention."

THE SUGAR BEET.

The sugar consumed in this and other countries up to 1850 was nearly all derived from the sugar cane, but at the present time two-thirds of the sugar crop is from the sugar beet. Between 1863 and 1883 Germany, one of the leading beet sugar producing countries, increased its output 338 per cent. It would once have seemed incredible that the kitchen garden should furnish a rival for the "noble plant" that had made the fortunes of Spanish and English colonists, but the cultivation of the beet has in one generation shifted the center of the sugar industry from the tropic to the temperate zone. This growth has been fostered by strange vicissitudes in the fortunes of nations, as the commercial embargoes and sugar bounties of the Napoleonic wars and by the emancipation of slavery in the British colonies, giving, as it did, a temporary check to the growth of the cane; but the real creators of the new industry were men of scientific training who solved certain botanical and chemical problems. The manufacture of sugar is now a chemical industry as much as is tanning and dyeing.

Marggraf, a chemist of Berlin, first discovered in 1747 that beets, with other fleshy roots, contained crystallizable sugar identical with that of the sugar cane. In 1796 Marggraf's pupil, Achard, erected the first manufactory for beet sugar, and in 1799 he brought the subject before the French Academy. He manufactured beet sugar on his farm in Silesia, and presented loaves of refined beet sugar to Frederick William III, of Prussia, in 1797; but the 2 to 3 per cent of sugar that could be extracted by the methods then in use was too small for commercial success. A new stimulus was given by the sugar bounties of Napoleon in 1806, and methods were rapidly improved, especially in France. Two great difficulties were still to be met; the percentage of sugar present in the beet was small (6 per cent), and it was separated with great difficulty from the many nonsugar constituents, some of them acrid and of very unpleasant taste. Science now came to the rescue, and a beet was gradually developed having a larger percentage of sugar and a smaller percentage of the undesirable impurities. Barber says that in 1836 18 tons of beet root was necessary to produce 1 ton of sugar; in 1850 this quantity was reduced to 13.8; in 1860, to 12.7 tons, and in 1889, to 9.25 tons. From 6 per cent of sugar as found by Marggraf the sugar beet of good quality now contains 15 per cent and more, 12 per cent being considered necessary for profitable manufacture.

THE SUGAR MAPLE.

The sugar maple of North America is also a source of sucrose, the trees being tapped in the early spring to obtain the sap as it flows upward. The sap was formerly simply boiled down in open kettles and used as molasses, or the evaporation was continued until the sugar crystallized and the brown maple sugar was obtained. Five gallons of sap yielded about 1 pound of sugar. Improvements in the process

have been devised. The sugar is now made more easily and quickly by the use of evaporating pans, etc. Maple sugar or sirup commands a higher price than white sugar from the beet or cane and is now used as a luxury because of its agreeable flavor, although it is still an article of regular diet in Lower Canada, as it was formerly among the farmers of New England and other regions. According to figures obtained from the United States Treasury Department, 6,000,000 pounds of maple sugar were produced in this country in 1894. These figures are based on the bounty paid to the sugar makers. A claim for bounty could not be made on less than 500 pounds. The amount of maple sugar produced, including that on which no bounty was paid, was over 7,500,000 pounds. Statistics later than 1894 were not available.

In this connection it is of interest to quote a paragraph from a book written by the eminent Robert Boyle and printed at Oxford in 1663:

> There is in some parts of New England a kind of tree * * * whose juice that weeps out of its incisions, if it be permitted slowly to exhale away the superfluous moisture, doth congeal into a sweet and saccharine substance, and the like was confirmed to me by the agent of the great and populous colony of Massachusetts.

The cane and the sugar beet are, however, the only important sources of sugar (sucrose). Of the world's crop of 7,707,500 tons in 1896, 2,747,500 tons were from cane and 4,900,000 tons from the beet.

QUALITY OF SUGAR FROM DIFFERENT SOURCES.

The methods used in the manufacture of sugar are all to the end of separating the sugar from the other constituents of the juice. In a word, the juice containing the sugar is expressed or extracted from the cane, beet, etc., treated to remove the nonsaccharin substances which prevent crystallization, evaporated in a vacuum apparatus, the sugar crystallized, and the crystals separated from the molasses in centrifugals. The sugar thus obtained, known as raw sugar, contains impurities from which it is separated by the processes of refining. The methods of manufacturing sugar have been described in a previous bulletin of this series.[1]

The average composition of raw sugar from a number of different sources is as follows:

Average composition of raw sugar.

Source from which obtained.	Water.	Cane sugar.	Other organic substances.	Ash.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Sugar cane	2.16	93.33	4.24	1.27
Sugar beet	2.90	92.90	2.59	2.56
Sorghum	1.71	93.05	4.55	.68
Maize	2.50	88.42	7.62	1.47
Palm	1.86	87.97	9.65	.50
Maple	.....	82.80	.....	.....

[1] U. S. Dept. Agr., Farmers' Bul. 52. The Division of Chemistry of this Department has issued a number of bulletins concerning the manufacture of sugar from sugar cane, sorghum, and sugar beets.

Raw cane sugar from these various sources takes on in each case the character of the impurities from which it has not yet been freed. Thus, the raw product of the sugar cane and sugar maple is pleasant in flavor, that of the beet acrid and disagreeable; the raw palm sugar or jaggary is of low sweetening power because of the large amount of invert sugar (dextrose and levulose, see p. 7) that has resulted from fermentation and too high a degree of heat used in evaporating it, while raw sorghum and maize sugar has each the characteristic taste of its sirup. From all these raw sugars the pure cane sugar or saccharose, as known to the chemist, can be crystallized out, and in every case the sugar is identical in chemical composition, appearance, and properties. By no chemical test can pure crystallized saccharose or "cane sugar" from these different sources be distinguished. There is a popular impression to the contrary, however, and it is often asserted that beet sugar has less sweetening power, or that fruits preserved with it do not keep as well, but this can only be true of specimens that have been imperfectly purified.

Methods of refining raw sugar have been so improved in the last few years that it may be truly said that few food substances are so nearly pure chemically as the best granulated or lump sugar. Blythe says:

> Loaf sugar is, as a rule, chemically pure. It is probably, indeed, the purest of all substances in commerce, and a large quantity may be burnt up without obtaining a trace of nitrogen and without leaving any residue. The only sugars that may be impure are the raw sugars.

Out of 500 samples of sugar examined by the Division of Chemistry of this Department[1] not one was found to be adulterated. The present low price of cane sugar protects it from such attempts.

FOOD VALUE OF SUGAR.

Our chief practical interest lies in the use made of sugar in the animal organism, or its food value. Within certain limits we can look upon sugar as the equivalent of starch that has been digested and made ready for absorption. A mealy boiled potato or a lump of laundry starch is in fact very near akin to a lump of sugar; and the potato, like all forms of starchy food, must be turned into a kind of sugar by the digestive juices before it can be absorbed as food by the system.

The statement is commonly made that the food eaten by the average adult is at least one-half of vegetable origin, and analyses show that the nutrients of vegetable foods are very largely starch. The average of 87 dietary studies made in the United States shows 45 per cent animal food and 55 per cent vegetable food. Starch furnishes a considerable part of the heat and muscular power of the body. Therefore starch or any food that will serve the same purpose is of great importance.

To understand this better we must follow the course of starch diges-

[1] U. S. Dept. Agr., Division of Chemistry Bul. 13, pt. 6.

tion. When starchy food, as a morsel of boiled potato, is taken into the mouth, it is at once acted on by a ferment contained in the saliva, and this action is continued by a ferment contained in the intestines. It is broken up into simpler chemical compounds and it finally reaches the blood and muscles as dextrose, a form of sugar which can be burned to yield heat and muscular energy. When an excess of carbohydrates (sugar or starch) is consumed, the dextrose in the digestive tract is converted in the liver to glycogen and stored until required, being then, it is believed, reconverted into dextrose. More complex changes may take place which convert carbohydrates consumed in excess into fat which is also stored as a reserve material.

DIGESTION OF SUGAR.

If a solution of cane sugar be injected into the blood, it is passed out by the kidneys unchanged, showing that it is not fitted for assimilation. The change needed, however, is slight compared with that required for the digestion of starch; it is "inverted" or changed into the simpler sugars as already described, and this change is brought about in the digestive tract by the agency of enzyms or ferments of whose nature we know little. When thus changed into the simpler sugars its function in the body is similar to that of starch after it has reached the analogous stage in digestion.

SUGAR AS A FOOD FOR MUSCULAR WORK.

Food must supply enough protein or nitrogenous material for the formation and repair of tissue and for certain other uses in the body and in addition sufficient nitrogen-free material to make up the required amount of energy necessary for heat and muscular work. Nitrogen-free material consists of fat and carbohydrates. In the ordinary diet the relative amount of fat and carbohydrates is usually regulated by personal preference. Fat will furnish two and one-fourth times as much energy as carbohydrates. Taking account of this fact it is immaterial on theoretical grounds which of these nutrients supplies the necessary energy, although this is, however, not the case from the standpoint of hygiene.

The main function of sugar as found in the blood, whether resulting from the digestion of sugar or of starch, is believed to be the production of heat and energy. The proof has been amply furnished by experiment. By ingenious devices the blood going to and from a muscle of a living animal may be analyzed and it is thus shown that more blood traverses an active or working muscle and more sugar disappears from it than is the case with a muscle at rest.

The question naturally arises, How does the sugar of our food differ from starch as a source of muscle power? The fact that we have in this manufactured article practically the same substance as that which results from the digestion of starch as found in vegetable foods at once

suggests its substitution for starch to the advantage of the system, since it does not burden the digestive tract and less force is required for its digestion. To decide this question much careful laboratory work has been carried on since 1893, when Mosso, an Italian investigator, first examined the influence of cane sugar in lessening fatigue. This he did by the use of the ergograph, an instrument devised by him for testing the work done by certain muscles of the hand. He found, as a result, that sugar in the food, in not too great quantities and not too concentrated, lessens or delays fatigue and increases working power.

Prof. Vaughan Harley continued these experiments in Mosso's laboratory, using much larger quantities of sugar, with the result that the amount of muscle work was greatly increased by it. He compared the work he could do in twenty-four hours fasting with what he could do when taking 500 grams (17½ ounces) of sugar dissolved in pure water, and found that on the sugar day he could do 61 to 76 per cent more work, or almost as much as on a full ordinary diet. When 9 ounces of sugar was added to the ordinary diet or to a meager diet, the gain in muscle-power was also considerable. The effect, although felt one-half hour after eating, was at its height in two hours. Very interesting also was the effect of sugar in delaying the natural coming on of fatigue which has been found to occur between 5 and 7 p. m. If three to four ounces of sugar were taken a short time before this hour the ordinary fatigue did not appear and work went on as usual.

The following year Dr. Langemeyer, working under the direction of Professor Stockvis, of Amsterdam, repeated these experiments with great care on several different persons, the work extending over a period of eight weeks. The ergograph, which recorded the amount of work done, was concealed from the person using it in order that he might not unconsciously influence the result, a caution not observed in Mosso's laboratory. Dr. Langemeyer obtained only negative results as to the effect of sugar on muscle work; an increase of muscle power occurred as often when no sugar was taken, or after a short rest, or after taking a drink of water.

At about the same time the Prussian war office authorized a test of Professor Mosso's results; the work was undertaken by Dr. Schumberg in Professor Zuntz's laboratory in Berlin, and the result was published February, 1898. The ergograph was used in this case also and the subject of the experiment, who was entirely ignorant of its nature, was given daily in addition to his other food 200 grams of a sweet fluid which on certain days was a solution of 30 grams of sugar and on other days was water made equally sweet with dulcin, a sweet-tasting chemical having no food value. By this precaution it was hoped to eliminate the influence which may have affected the results of Mosso and his pupils, even against their will. The results seemed at first to corroborate those of the Amsterdam laboratory and thus to deny any immediate effect of sugar in increasing muscle power. When, however, the subject of the experiment performed some very exhausting work,

as with a lathe, before beginning on the ergograph, the difference in the effect of dulcin and sugar became very apparent, the sugar restoring to some extent the efficiency of the tired muscle, while dulcin did not. The explanation given was that a little more or less sugar in the blood was of no consequence in ordinary exertion, but it was otherwise when the sugar stored up in the muscles was heavily drawn upon by exhausting labor. At such a time the rapidity with which sugar is digested and absorbed proves a great advantage.

In effect Dr. Schumberg says: "The practical conclusion to be drawn is that sugar in small doses is well adapted to help men to perform extraordinary muscular labor." He advises practical tests of his results on a large scale in which small amounts of sugar in some refreshing drink, as lemonade, will be given to men fifteen or twenty minutes before they begin a piece of very hard work or at the first signs of exhaustion. If the sugar is to be taken in solid form he recommends chocolate as the best medium. The application of these results to the food of soldiers who may be called upon for extraordinary exertion in marching or fighting is very evident.

Following on this work of Schumberg's came a practical test made with soldiers of the German army during the autumn maneuvers, the observation extending over thirty-eight days. A number of men were given 10 lumps (70 grams, or about one-sixth pound) of sugar daily and were compared in various ways with men performing the same amount of work in marching and drilling, but whose food contained little or no sugar. The results were in every way to the advantage of the men using sugar. The sugar was relished during the whole time. On long marches it appeased hunger and mitigated thirst; a feeling of refreshment followed which helped the tired man on his way, and none of the soldiers allowed sugar were at any time overcome by exhaustion. It was found that both their pulse rate and breathing were less affected by exertion than was the case with the men consuming no sugar. On the basis of these results the military surgeon making the investigation recommended that the sugar ration for soldiers be raised to 60 grams daily, and that it be furnished as sugar for coffee and in sweetened food, preserves, or honey. It was recommended, further, that sugar be supplied to prisons, hospitals and ships, its fine keeping qualities and condensed form making it especially valuable in certain cases. The value of glucose as a muscle food has been recently shown by methods similar to Schumberg's.

It is believed that more satisfactory results may be obtained by experiments with men and animals in which the effects of given quantities of sugar in the diet are compared with those obtained with starch and other food materials. Such experiments with men in the respiration calorimeter are now being made under the auspices of this Department. They make it possible to measure with great accuracy the relation between the material consumed and the muscular work done.

According to our present knowledge, the value of sugar as a food for muscular work may be briefly summarized as follows:

(1) When the organism is adapted to the digestion of starch, and there is sufficient time for its utilization, sugar has no advantage over starch as a food for muscular work except as a preventive of fatigue.

(2) In small quantities and in not too concentrated form sugar will take the place, practically speaking, weight for weight, of starch as a food for muscular work, barring the difference in energy and in time required to digest them, sugar having here the advantage.

(3) It furnishes the needed carbohydrate material to organisms that have as yet little or no power to digest starch. Thus, milk sugar is part of the natural food of the infant.

(4) In times of great exertion or exhausting labor, the rapidity with which it is assimilated gives it certain advantages over starch.

This latter quality, which renders it more rapidly available for muscle force, may, perhaps, account for the fact that sugar is so relished by people who are doing muscular work and by those of very active habits, as children.

The American farmer ranks high among agriculturists as a rapid and enduring worker, and his consumption of sweets is known to be very large. The same is true of lumbermen and others who work hard in the open air. Col. Henry Browne, quoted by Dr. Harley, says:

> The lumbermen of Canada, than whom no finer or more muscular men exist, eat a great deal of sugar in the form of molasses. They fill their milkless tea with it, make cakes with it, and even add it to their fried fat salt pork, which is the only meat they get during the whole time they are in the woods cutting lumber, and this is practically half the year, their diet when at home being much the same.

In connection with the nutrition investigations carried on by this Department the dietary of the negroes in Alabama on the edge of the so-called "black belt" was studied. The staple articles of diet were found to be salt pork, corn meal, and molasses. The molasses was made from sorghum or sugar cane. It was often a domestic product. When this supply was not sufficient a commercial molasses was purchased. Molasses was eaten mixed with the fat obtained when fat salt pork was fried. This mixture, with corn bread and fried pork, formed the basis of the regular diet for each meal every day in the year, some green vegetables being occasionally added. Hot water sweetened with molasses was the beverage used with the meals. It should be added that this diet was not considered satisfactory by those making the investigation, it being deficient in nitrogenous material.

The value of sugar in cold climates, where foods containing starch are not produced or can not be kept, is evident. In the outfit of polar expeditions sugar is now given an important place, and it may, in time, take the place of part of the large amount of fat eaten by the Eskimos and other inhabitants of the polar regions.

It is in warm countries, however, that sugar plays the greatest rôle,

for there very little fat is eaten. In India it is said that workmen must have, daily, large amounts of food well seasoned with sugar. The employer must furnish it or lose his workmen. In all tropical lands the consumption of dates, figs, and other sweet fruits is very large.

Certain rowing clubs in Holland report very beneficial results from the use of large amounts of sugar in training. It seemed to counteract the bad effects of a meat diet, so that the dreaded symptoms of overtraining did not appear. The rowers who used sugar always won because of superior endurance.

One case as given in detail is very interesting. Two schoolboys, 17 and 19 years of age, with only two hours a day for practice, at the end of two months entered for the rowing races. No change had been made in their diet except that they ate as much sugar as they wished, sometimes as much as one-third of a pound at the time of their daily exercise. One of them, however, did not make this addition to his diet until the third week, when he began to show all the signs of overtraining—loss of weight, and a heavy, dull feeling, with no desire for study. On the third day after beginning the use of sugar these symptoms disappeared. At the time of the race both youths were in fine condition and were victorious over their antagonists, who did not believe in the use of sugar. No after bad effects were observed.

Professor Pflüger says that, without doubt, the sugar in the blood is heavily drawn on during violent exercise; hence the longing for it in a form that can be rapidly assimilated.

Mr. Charles E. Courtney, trainer of the Cornell University boat crew, recently informed the writer that the men in training seemed to crave sugar, and they were allowed all they wanted on cereals, in tea, coffee, etc., but he objected to it in pie and cake.

Its use by mountain climbers is well known. The Swiss guide considers lump sugar and highly sweetened chocolate an indispensable part of his outfit.

SUGAR AS A FAT FORMER.

Sugar, like starch, is fattening; that is, when taken in excess it may be transformed into fat and stored as reserve material. On this account physicians advise that sugar be sparingly used by the corpulent.

Both molasses and sugar have been successfully used in fattening cattle and pigs, the fat being found to be firm and of good quality. With cattle, 500 grams a day were profitably eaten.

It is said that in Santo Domingo, at times when the importation of grain has been suspended for lack of ships, raw sugar has been used to fatten horses and cattle for months together.

SUGAR AS A FLAVOR.

As mixed with other foods, sugar is one of our best flavors—a flavor which the cook could not readily spare, as it now enters into a great

variety of dishes. Its agreeable flavor has always constituted one of the chief reasons for its use, and will continue to do so, since we have such an abundance of relatively cheap starchy materials which may readily take the place of sugar as food.

In some dietary studies made under the auspices of this Department with a club of students at the Maine State College, the effect was studied of supplying a liberal amount of maple sirup in connection with a diet which was known to furnish an abundance of nutrients. The sirup was evidently relished, and considerable amounts were eaten. However, there was not a corresponding decrease in other foods; on the other hand, the amount of flour was in excess of the amount ordinarily consumed. It would seem that the maple sirup and flour, in the form of griddle cakes, were consumed simply on account of their agreeable flavor. Provided the diet contained sufficient nutrients in the first place, this increase was not desirable on the ground of economy, and it may be questioned whether it was desirable from the standpoint of health. When a similar comparison was made of the addition of milk in liberal amounts to the diet it was found there was a corresponding decrease in the amount of other foods consumed.

This investigation would indicate, as stated above, that sugar is consumed for its agreeable flavor and not because it is recognized as a food.

FOOD VALUE OF MOLASSES.

Besides some cane sugar, molasses contains about 30 per cent invert sugar, about 30 per cent water, and certain acids and other bodies of which we know little. It also contains impurities accidentally present. Molasses was formerly the drainage or refuse from the manufacture of cane sugar, but with modern methods of sugar making this source of supply has become entirely inadequate. Small planters in Louisiana and elsewhere who have a limited tract of cane under cultivation still follow the old method of sugar making without the help of vacuum pan and centrifugal. The molasses drains from the brown sugar and is called "open-kettle" molasses. It commands the highest price on account of its fine flavor, but this variety is almost all consumed in the locality where it is made. Much that is now sold as New Orleans molasses is glucose or starch sugar colored and flavored with some molasses from the sugar factories. Glucose is used to give molasses a body and a lightness of color that is in demand, and this mixture is now preferred quite generally to the old-fashioned dark molasses. In consequence of the preference for a light-colored product, molasses not mixed with glucose is bleached to improve its color. The bleaching agents are generally of a deleterious character and must be very carefully removed when they have done their work. It is the possible presence of these agents, rather than that of glucose, that suggests caution in the use of molasses in quantity. Glucose, as we have already said, if carefully made is not considered injurious.

No molasses for table use is made from the sugar beet, as it is impossible to free the uncrystallizable part from the objectionable impurities. Maple sirup or molasses is the sap of the sugar maple which has been boiled down, but not sufficiently to cause the sugar to crystallize. The high price of maple molasses or sirup has led to extensive adulterations of the product with cane sugar and glucose, the flavor being often furnished by an extract of hickory bark.

In the United States a considerable quantity of molasses is made from sorghum. It is consumed for the most part in or near the locality where it is made.

NUTRITIVE VALUE OF SUGAR CANE.

The entire juice of the ripened cane is of course more nearly a complete food than is crystallized sugar, for it contains other constituents besides carbohydrates. It is elaborated by the plant as a rich plant food used to build up young leaves and buds. In sugar-producing countries the cane is said to be a staple food during its season. All classes of people chew the ripe cane freed from its hard rind, incredible quantities being consumed in this way. Shiploads are brought daily to the markets of Rio Janeiro, New Orleans, and the West India towns. For months the chief food of the negro laborers on the plantations is said to be the sugar cane, and they are seen to grow strong and fat as the season advances. They go through the hard labor of harvesting the crop and come out in fine condition, although they began it weak and half starved.

Wray says: "The nutritious and fattening qualities of the sugar cane are abundantly shown on every sugar estate in the world." Another writer says: "From their free use of the cane juice the negroes of the West Indies and every animal about the plantation at the time of harvest show every indication of the wholesome and nutritious properties of the juice."

A curious book, entitled A Treatise on Sugar, written by Dr. B. Mosely, and published in 1799, has the following:

> In the West Indies the negro children from crude vegetable diet are much afflicted with worms. In crop time, when the canes are ripe, these children are always sucking them. Give a negro infant a piece of sugar cane to suck and the impoverished milk of his mother is tasteless to him. This salubrious luxury soon changes his appearance; * * * his emaciated limbs increase, and if the canes were always ripe he would never be diseased. I have often seen old, scabby, wasted negroes crawl from the hot houses, apparently half dead, in crop time and by sucking canes all day long they would soon become strong, fat, and sleek.

La Gazette de Santé, 1785, narrates that a vessel from the West Indies laden with sugar encountered a calm, which so delayed her that provisions were exhausted. The crew then had recourse to the cargo; some sailors had already died of scurvy and many were threatened with death, but this disease abated when its victims were of necessity

reduced to a sugar diet. The sugar in this case was undoubtedly raw or crude sugar, and it may well have had this effect by virtue of the potassium salts contained in it.

PRACTICAL USE OF SUGAR IN DIETARIES OF ADULTS.

Sugar was formerly regarded as a condiment and valued chiefly for its pleasant taste. Had it in reality no other use it might in time be replaced by other sweet-tasting substances, as saccharin and dulcin, which are not foods, but the food value of sugar has been fully established, and, considering the immense quantities at present consumed, it is very important to determine the extent of its usefulness in dietaries.

It has been ascertained that in large numbers of well-to-do families in our country about 2 pounds per week per person is consumed. It would seem that this amount, or about one-fourth of a pound daily, taken as it is in connection with other foods, is well utilized by the system. Regarding larger quantities there is some question. The use of sugar would seem to be limited in two ways: (1) By the fact that sugar may be absorbed more rapidly than it can be assimilated and thus overload the system, bringing on indigestion or overloading the excretory organs; (2) by the ill effects on the system of concentrated solutions of sugar.

AMOUNT AND CONCENTRATION.

Regarding the amount that can be properly used in the system, sugar differs greatly from starch. Starchy food, as bread, potatoes, etc., can be digested and utilized in immense quantities. Rubner reports that food containing over 600 grams (1⅓ pounds) of starch a day is digested without difficulty and over considerable periods of time. This amount of starch would be represented by 2½ or 3 pounds of bread or 6 or 7 pounds of potatoes.

Fewer tests have been made regarding the maximum amount of sugar that may be used by the system. Vaughan Harley used large quantities of sugar in his experiments already quoted, but 400 grams (nearly a pound) daily for some time very much affected his digestion.

Since, as scientific investigators seem agreed, the digestion of sugar is much more rapid than that of starch, assimilation and storage in the liver can not keep pace with its absorption in the intestines if it is taken in large quantities. In this case part of the sugar will be excreted unchanged. Not only is this excess of sugar wasted, but such an unnatural tax on the excretory organs would soon end in disease. It is also a matter of common observation that large amounts of sugar and sweetened food are apt to ferment in the stomach and intestines. This prompt refusal of the system to utilize large amounts of sugar at a time is a sign that must be heeded. It shows that the eating of sugar can easily be carried too far.

It has been pointed out by investigators that in this regard sugar bears much the same relation to starch that peptone, one of the products of meat digestion, does to meat. Both sugar and peptone are very diffusible, and thus enter rapidly into the circulation, strong solutions at the same time irritating the mucous membrane with which they come into contact by virtue of their water-abstracting power. In cases of weak digestion peptone and albumoses, or meat artificially digested, is given, that the system may be nourished with as little tax as possible on the digestive organs. But in the case of a man in health, if the peptone is substituted entirely for the natural food it brings on irritation of the intestinal canal, with diarrhea and other symptoms of indigestion.

Brandl, a German scientist, made experiments on the effect of sugar solutions of different strengths on the stomach of a dog. A solution of 5.7 per cent reddened the mucous membrane; a 10 per cent solution made it dark red, indicating great irritation; a 20 per cent solution caused the dog such distress that the experiment was carried no further. It is quite possible that this effect is produced on the human stomach when large quantities of sugar in concentrated form, as candy, are eaten.

Chaveau, a French investigator, in his experiments with dogs, found that when used in considerable amounts sugar was so laxative in its effects as to interfere greatly with his work; yet he found, as have others, that sugar was a source of energy, and his conclusion was that it has a higher value as compared with fat than is ordinarily assigned to it. It must be remembered that sugar is a powerful antiseptic or germicide. In a strong sirup of sugar fruits, vegetables, and even meats may be preserved. This property of sugar was well understood when it was used only as a medicine, for it was even sprinkled on wounds to keep them from mortifying. An agent of this kind in concentrated solution must not only hinder putrefactive processes, but also retard the process of digestion. Thus, Ogata found in experiments with dogs that the addition of 10 grams of cane or grape sugar to 100 grams of meat fibrin caused 18 to 27 per cent of it to remain undigested as compared with normal digestion. With our present understanding of the amount of absorption going on in the stomach, we can not state positively that such a delay is in itself disadvantageous.

It will be noticed that sugar as it exists in nature—e. g., in the sugar cane, in milk, and in most fruits—is not highly concentrated. In milk it makes up from 4 to 6 per cent. It would seem that the animal organism is best adapted to the utilization of food principles in the somewhat dilute or bulky form in which they occur in the commonly accepted foods—protein as found in meat, milk, etc., starch in grains, and sugar in small quantities as found in vegetable juices and milk, and in reasonable amounts in combination with other foods—and that it does not readily accept unlimited amounts of chemically isolated and purified food principles.

BAD EFFECTS ASCRIBED TO SUGAR.

Most of the bad effects ascribed to sugar are due to its use in larger quantities than the 3 or 4 ounces a day which seem to be digested by the healthy adult without difficulty, if it is not presented in indigestible forms. There is no proof that sugar is harmful to the teeth, although doubtless sweet food, allowed to cling to the teeth after eating, rapidly ferments and acids will be formed that, according to Professor Miller, of Berlin, may attack the teeth. This is equally true of starchy foods. It is said, however, that the negroes of the West Indies, who consume enormous quantities of sugar, have the finest teeth in the world.

It is also unproved that sugar produces gout.

Sugar seems ill adapted to the sick, except when used in very small quantities as a flavor. Jacobi remarks that in sickness the stomach is inactive, has less absorptive power, and that sugar on that account is less well borne. The action of sugar in stimulating a flow of the digestive juices may in such a case be only irritating in its effect.

EFFECT OF EXERCISE ON THE AMOUNT OF SUGAR WHICH MAY BE EATEN.

The amount of sugar that may be eaten without bad effects depends much on whether a person leads an active or a sedentary life. It has been observed that a man doing hard work in the open air can easily assimilate large amounts of sugar, while the same quantity would bring on indigestion if taken when he is living indoors, with little exercise.

SUGAR IN COOKED FOODS.

What has been said of the food value of sugar applies to it as a solution in water and in various drinks, as tea, coffee, etc. The food value of sugar as taken in cake, pastry, custards, and other cooked foods is probably somewhat modified; but few tests have been made in the digestibility of such foods.

CONFECTIONERY.

Candy of the better grade is very largely made up of sugar, with the addition of various coloring matters and flavors, nuts, fruit, etc., and sometimes fat, starch, and glucose. The food value of candy may be expressed by the amount of the sugar contained (72 to 96 per cent), but the wholesomeness of the other ingredients must be taken into account. The coloring matters used in cheap candies are nearly all compounds of anilin or other coal tar products, some of which are thought to be harmless, while regarding others there is more doubt. Two hundred and fifty samples of cheap candy examined by the Division of Chemistry of this Department a few years ago were found to be made up largely of glucose with a little sugar and starch. Pure glucose is no longer

considered an injurious adulterant. Some of the coloring matters and flavors used, however, have been shown to be harmful. Ordinary caution would suggest that children, at least, be allowed to partake very sparingly of such unknown compounds. It is to be remembered also that glucose, being more rapidly absorbed than is cane sugar, may overload the system more easily. It also undergoes fermentation more readily.

SUGAR IN THE DIETARIES OF CHILDREN.

The amount of sugar to be given to children, and in what form, is a question of much importance. Sugar would seem to be a food especially adapted to children because of their great activity. The small organism loses more heat from the skin for every pound of body weight than does the larger animal, and children on this account, and because of their active life, require proportionately more heat units in their food than do adults.

Fat, especially fat meat, which could readily supply this need, is often disliked by the child, and his relish for all kinds of sweets has doubtless a physiological basis. It is, however, to be remembered that before its introduction countless generations of children had been reared without the help of cane sugar as we now know it. The digestibility of sugar and sweetened foods for children, and the influence on the appetite for other foods, must decide to what extent sugar is to replace starch in the dietary and how far it may be safely used as a flavor.

Until a child's stomach is capable of digesting starch the needed carbohydrate is furnished in the sugar of milk, the child a year old who drinks two quarts of milk a day taking in this way about three ounces of sugar. As the stomach becomes able to digest starch the child is less and less dependent on the sugar of milk, replacing it with the carbohydrates of vegetable origin, while the proteids and fat found in eggs, meat, and cereals take the place of those constituents that were at first exclusively furnished in milk. Milk, however, remains through childhood a valuable source of all these food principles.

The fact that sugar has a high food value is not the only point to be considered. The child will easily obtain the needed carbohydrates in other forms and will thrive if the digestion remains sound and its relish for wholesome food unimpaired. For instance, one often hears it said that a certain child does not relish milk. In such cases it might be found that the child's appetite, being sated by sugar in other foods, is no longer attracted by the mild sweetness of fresh milk, delicious as it is to the unspoiled palate. It would be well, perhaps, in this instance, to cut down the allowance of sugar in the hope of restoring the taste for so invaluable a food as milk. Dr. Rotch insists that the infant, even in its second year, should never be allowed to taste sweets. He says, "When these articles are withheld it will continue to have a healthy appetite and taste for necessary and proper articles of food."

Even much later, for the same reasons, the introduction of large amounts of sugar into the daily food of children is to be carefully considered. Children do not require a variety of flavors to stimulate the appetite, but the taste is easily perverted and the backward step is difficult to take. Those who have studied the food habits of children seem to agree that sugar should from the very first be withheld from the dish that forms the staple food of the child—that is, the mush or porridge of oatmeal or some preparation of wheat or corn. This article of diet, eaten only with milk or cream, falls into the same class as bread and milk, and forms the simple, wholesome basis of a meal. The sugar given the child is better furnished in the occasional simple pudding, in the lump of sugar, or homemade candy, not that its food value is better utilized, but the whole food of the child is thus more wholesome.

In sweet fruits fully ripened the child finds sugar in a healthful form and they should be freely furnished.

GENERAL CONCLUSIONS.

One may say in general that the wholesomeness of sweetened foods and their utilization by the system is largely a question of quantity and concentration. For instance, a simple pudding flavored with sugar rather than heavily sweetened is considered easy of digestion, but when more sugar is used, with the addition of eggs and fat, we have, as the result, highly concentrated forms of food which can be utilized by the system only in moderate quantities and which are always forbidden to children and invalids.

It is true that the harvester, lumberman, and others who do hard work in the open air consume great amounts of food containing considerable quantities of sugar, such as pie and doughnuts, and apparently with impunity; but it is equally true that people living an indoor life find that undue amounts of pie, cake, and pudding, with highly sweetened preserved fruit, and sugar in large amounts on cooked cereals, bring indigestion sooner or later.

From a gastronomic point of view it would seem also that in the American cuisine sugar is used with too many kinds of food, with a consequent loss in variety and piquancy of flavor in the different dishes. The nutty flavor of grains and the natural taste of mild fruits is concealed by the addition of large quantities of sugar.

In the diet of the under nourished larger amounts of sugar would doubtless help to full nutrition. This point is often urged by European hygienists. In the food of the well-to-do it is often the case, however, that starch is not diminished in proportion as sugar is added. That sugar on account of its agreeable flavor is a temptation to take more carbohydrate food than the system needs can not be denied. The vigor of digestion in each particular case would seem to suggest the limit. A lump of sugar represents about as much nutriment as an

ounce of potato, but while the potato will be eaten only because hunger prompts, the sugar, because of its taste, may be taken when the appetite has been fully satisfied.

Sugar is a useful and valuable food. It must, however, be remembered that it is a concentrated food and therefore should be eaten in moderate quantities. Further, like other concentrated foods, sugar seems best fitted for assimilation by the body when supplied with other materials which dilute it or give it the necessary bulk.

Persons of active habit and good digestion will add sugar to their food almost at pleasure without inconvenience, while those of sedentary life, of delicate digestion, or of a tendency to corpulency would do better to use sugar very moderately. It is generally assumed that 4 or 5 ounces of sugar per day is as much as it is well for the average adult to eat under ordinary conditions.

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